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H. Sheridan Stone

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Center

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HAWAIIAN MONK SEAL POPULATION RESEARCH, LISIANSKI ISLAND, 1982

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ABSTRACT

The absolute number of animals in the Hawaiian monk seal, Monachus schauinslandi, population at Lisianski Island was determined by identifying individuals on the basis of applied bleach symbols and natural marks, and conducting 98 island censuses from 17 March to 14 September, and 26 October to 22 November 1982. The extensive data base obtained by these marking and census methods should provide specific quantitative information that may be useful in the interpretation of future census and population data from islands used by Hawaiian monk seals. The alternate day censuses provided data on temporal and spatial haul-out patterns for individual seals. Data were collected daily on pupping, weaning, molting, and other factors that may influence haul-out patterns. Injuries and deaths were documented.

In addition to 28 pups of the year, 215 seals consisting of the following were identified: 18 male and 10 female juveniles, 24 male and 21 female subadults, and 101 male and 41 female adults. Only two of these seals (an adult female and adult male) were known to have moved to Lisianski Island from other islands during the study. Three pups died, and a subadult female disappeared and is presumed dead. There were three serious injuries: two adult females with dorsal wounds, and a shark-injured adult male.

INTRODUCTION

Direct counts of the Hawaiian monk seal, Monachus schauinslandi, over the last two and a half decades have indicated changes in abundance at all major islands in the Northwestern Hawaiian Islands (Johnson et al. 1982). The overall population trend has been a marked decline, but the counts are only an index of relative abundance. Until the late 1970's, constraints of time and logistics prevented standardization of census methodology among years or atolls. Tagging and marking data have been valuable in estimating reproductive rates and intervals, and in better understanding interisland movement (Kenyon and Rice 1960; Wirtz 1968; Johnson and Kridler 1983). But little current information is available on age- or sex-specific survival, and there are few detailed data on individual haul-out probabilities by sex, age class, or season with which to adjust census data for missed seals. Interisland movement appears to be low (Johnson et al. 1982), but its exact influence on parameters at the population level is unknown, and just how open or closed the subpopulations are has not been determined.

To obtain more precise information on Hawaiian monk seal population dynamics, studies were conducted on Lisianski Island from 17 March to 14 September and 26 October to 22 November 1982. The findings of this population study are described in this report. Other studies simultaneously conducted by the Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service (NMFS) researchers at Lisianski on pup tagging evaluation, association behavior, restraint and instrumentation of seals, diving and haul-out patterns, and entanglement in debris will be reported elsewhere.

Population studies on Lisianski Island in 1982 centered on marking all seals that hauled out and conducting a long series of frequent censuses of the entire island. The objectives were to obtain data for evaluating various population estimators, obtain an absolute count as a reference for the estimation techniques, and document detailed haul-out patterns of individuals and factors that affect them. Accomplishing these objectives will lead to standardized methods that may be applied in future years on more islands to accurately estimate monk seal populations and precisely monitor trends.

AREA AND METHODS

Area

Lisianski Island (lat. 26°02'N, long. 174°00'W) in the Hawaiian Archipelago (Fig. 1) is the single island on Neva Shoal, a large reef bank described in detail by Clapp and Wirtz (1975). A few very small offshore projections of coral are awash at low tide, but usable seal haul-out sites more than a few dozen meters off Lisianski, and thus unobserved on census, are considered negligible. Several meters or more inland from the shoreline there is mostly continuous vegetative cover. This usually dense, low vegetation often obscures seals hauled up beyond the beach for the night or during windy, rainy, or cool weather. This vegetation also

provided cover at times for observers to minimize likelihood of seal disturbance, in general, and, in particular, to avoid affecting haul-out patterns.

Lisianski is about 240 km southeast of Pearl and Hermes Reef, which is composed of several islets and supports a small seal population (Johnson et al. 1982). It is about 215 km west of Laysan Island, which has a seal population apparently greater than Lisianski's. These are the two monk seal populations nearest Lisianski.

The island perimeter was divided into 49 sectors of varying length, delineated as much as possible by long-term natural landmarks (Fig. 2).

Population Marking

Age Classification

A seal to be marked was assigned an age class, then assigned a two-digit (pup) or three digit symbol from a series for that class. Marking emphasis initially was on adult females, especially those apparently pregnant, then on immature seals before they began molting, and finally on adult males.

Seals were classified directly into their "age group" based on known age (pups-of-the-year, nursing, or weaned) or reproductive state (adult females with pups), or indirectly based on an estimated "age class." This latter classification included three groups:

Juvenile: Short, slight seals from the length of a weaned pup (about 138 cm) to 20-30 cm longer. Immature seals including yearlings, and perhaps younger seals, up to perhaps 3 years (Johnson and Johnson 1981a). Distinguished from pups by thinness and pelage color. Sometimes differentiated into J1 or J2, where J2 is larger.

Subadult: Seals perceptibly longer than juveniles up to breeding size; less robust than adults, generally with lighter pelage. Immature seals likely from 3 or 4 to 5 or 6 years.

Adult: Reproductively active or breeding size seals at least as long as known breeders. Mature or probably mature seals. Adult females often have extensive back scars or wounds; adult males usually dark, including venter, and extensively scarred.

Aging was primarily based on estimated seal length, but girth, pelage appearance, scarring, and behavior were sometimes used secondarily. This assignment of marked seals to estimated age classes was based on reassessment over time and consensus among observers involved in taking censuses.

Marks and Application

Seals were considered marked when identifiable by one or more natural or applied marks that met minimum criteria of distinctiveness and conspicuousness. Before new marks were applied seals were carefully examined for any existing bleach marks and for scars and pelage patterns. As more seals were marked, the necessity of careful examination for previous marks (bleach or scars) became increasingly important to minimize chances of double marking. For a few seals, scars extensive enough to be visible regardless of how the seal lay were used as the sole identifying mark. Scar identification was also used temporarily for unbleached females with pups, because lactating females were never bleached while they had nursing pups to avoid disturbance. Both groups were bleach marked soon after weaning, and an effort was made to reidentify the known mothers from their scars when they returned ashore. Half of the 26 weaned pups in 1982, randomly chosen as they weaned, were also double tagged on the hind flippers with green Temple[2] tags.

The seals were marked with Lady Clairol Ultra Blue or Clairolite hair lightener, mixed with developer, with varying success under differing conditions. Woolite red or blue sheep marking paint was also used, and both colors could provide conspicuous marks, though they remained so for only up to 3 weeks. The fluid was squeezed from a plastic bottle onto the most dorsal aspect reachable, without actually touching the sleeping seal. Bleaching anterior parts of the flank was avoided since seals readily scratched these areas with a foreflipper, and then often rubbed the mouth and eye region with the same flipper. A single transverse rump line was also applied, girdling as much of the dorsal and lateral pelvic region as possible. This was valuable in recognizing a seal as "marked" even if its identifying number was not visible.

Mark Recording

Marks were carefully sketched on a card for each seal, along with other scars and natural pelage marks. Behavior at time of marking such as rolling and smearing bleach or entering into the sea was recorded. Updating and amending these cards, and photographing marked seals, were continuing processes to maintain a current file of known seals.

When first resighted, a new bleach mark on a seal was noted as to its contrast against surrounding pelage and its legibility as a unique mark. If necessary, rebleaching was done to protect census data reliability. This was important to maintain the validity of the assumption that all marks present were seen, or at least to keep violations of the assumption to as few as possible.

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[2] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Monitoring and Maintaining a Marked Population

Behavior and events influencing seal haul-out patterns and survival were monitored daily and during censuses. Dates of pupping, weaning, molt period, appearance of fresh wounds, and death were collected on a daily basis. These events affect probability of sighting a specific seal during a specific census, as well as the correlation of sighting in consecutive censuses.

Molt

Seals were monitored at least daily through their molt to record start and finish dates, percent molted by increments of 5%, and movements around the island, as well as to rebleach them. When about 70% or more molted, approachable sleeping seals were rebleached to maintain identity.

Census Methods

Census procedures were designed to take advantage of an extensive field stay and intensive marking and census effort in 1982. At the same time, a protocol was designed that could be repeated on other islands in shorter visits, so comparative analyses among islands and years would be valid.

Observers

From two to six field biologists were present on Lisianski from 17 March to 14 September and from 26 October to 22 November 1982. Census areas were divided between two, or when present, three observers--the same three people as long as they remained on the island. This continuity of census takers served to minimize census duration and increase or maintain accuracy of identification and consistency in age-classing seals. The experience developed was important in minimizing disturbance of seals, especially lactating females, while ensuring standard census protocol.

Time of Censuses

Complete island censuses were taken every second day except when this pattern was broken on four occasions. When this 2-day interval between censuses was increased to 3 or 4 days in these exceptions, a new alternating day schedule was started. Eighty-five censuses were taken during spring through summer, and 13 in autumn. All were sequentially numbered, 1 through 98. Censuses began at 1300 Honolulu time, when the number of seals hauled out was near its highest (Kenyon and Rice 1959; Butler and Udvardy 1966; Johnson and Johnson 1981b), and took 1-1/2 to 2-1/2 h.

Census Procedure

Each observer walked one part of the shoreline. Observers exchanged sections for each census, but a particular area was almost always walked in the same direction.

Census takers with binoculars moved along the berm above the beach while looking and listening for seals that may have been in vegetation ahead or inland of the census route. All seals that were hauled out completely enough to be inspected for identifying marks in a given sector, while the observer was in that sector, were recorded there. That is, seals in the water, or that hauled out after the observer moved through that sector, or that only briefly hauled out in a sector ahead were not formally counted. (For other purposes the occurrence and identity of some of these seals may have been recorded, such as documenting seals "using" the island a given day but missed on census.)

Seals that swam by but did not haul out were ignored, since the probability of such a seal being counted only once could not be determined. Such a probability was dependent on that seal's swimming direction relative to the directions of converging or diverging observers. This potential census error was minimized in two ways. Censuses were taken in as brief a time as possible to avoid movement effects, and multiple resights of known seals in different sectors were documented.

Sex and Age Classification on Census

Each observed seal was recorded by age class on each census. This procedure was meant to precede and be independent of the identification process, since awareness of a known seal's assigned age (see marking section) would influence any estimate of age and prevent understanding of observer bias or error. Conversely, comparison of an independent estimate with the assigned age after identification helped standardize age-classing between observers and observations. A concentrated effort to standardize age-classing among observers was made at the start of the season.

The sex of seals was categorically recorded only when actually determined, or if the sex of a positively identified seal was known. When appearance, behavior, or limited ventral view strongly indicated a seal's sex, that conjecture may have been noted on census if no confirmation was made after a wait of up to 15 min.

Seal Identification on Census

Identity of a seal was recorded when enough of a mark was seen to positively identify it and eliminate all others. The identification process rapidly became more reliable and easier for observers as they developed skill and confidence in discerning marks and familiarity with scar patterns and with mark appearance, location, and orientation on individuals. Up to 15 min may have been spent waiting for a seal to expose an aspect or show a better mark. If a group of seals was being observed, waiting time could accordingly be longer.

If for any reason a seal could not be carefully and completely observed, or a mark not sufficiently read, this was noted (e.g., "left flank unseen," "too sandy"), the presence of any mark recorded, and what was seen of the mark sketched when possible. Each sketch of scars or partly seen marks was later compared with cards on file documenting marked

seals similar to the age and sex of the unidentified seal. Determination of two of the three figures in a bleach mark was almost always sufficient to allow positive identification. If, after this, identification was still inconclusive, the sketch was saved for future checking as file cards were amended or for confirmation when that seal was resighted.

Molt Status on Census

Molting seals were noted, and percentage of total body area molted was estimated in 5% increments. Observer agreement on molt estimates was found through regular comparisons to be consistently within 10-15%; thus overall differences were negligible. Degree of molt was often secondarily useful in identifying seals, and recording these data was part of a daily effort to monitor molting seals.

Multiple Sightings

Known resights of a seal on a given census were handled in one of two ways: 1) any seal that hauled out two or more times within full view of a census taker was recorded only once, and 2) seals resighted farther away from their first appearance were tallied in as many sectors as they appeared. This was assumed to be the best way to allow adjustment and valid application of Lisianski census results, either by deleting resights for accuracy of 1982 data, or including them to make the data more directly comparable with data sets in which few or no seals were marked. Through the early part of our season, as more seals were marked, the recorded prevalence of multiple countings was expected to increase proportionately.

RESULTS AND DISCUSSION

Results of Field Methodology: Individual Level

Marking

The number of monk seals older than pups identified by scars or artificial marks on Lisianski this season totaled 215. Table 1 shows the breakdown by sex and assigned age class, including one late season immigrant adult male (No. 166).

All juvenile females were marked by 29 May, and all males by 4 June. All subadult females were marked by 2 June, males by 8 June. The last adult female, before the arrival of No. 165 from Laysan on 22 July, was marked on 3 June. The first 91 adult males were marked by 8 June, the last 10 from 17 June to 10 August, until the initial appearance of No. 166 on 4 September.

Application of unique, conspicuous marks to the pelage of a sleeping monk seal is practical and can be effective for all sex and age groups. Paint has short-term usefulness, since it persists dependably for only 3 weeks or less, but its consistent viscosity often makes it easier and quicker to apply than bleach and may be of some use as a temporary, usually quite conspicuous mark.

Table 1.--Lisianski Island 1982 monk seal population, showing all seals marked including two mortalities, based on estimated midsummer ages.

	Male	Female	Total	Sex ratio male to female
Juvenile	[1]18	10	28	1.8:1
Subadult	24	[2]21	45	1.2:1
Adult	[3]101	[4]41	142	2.5:1
Total	143	72	215	

[1]Number assumes that No. J39 = No. J45.
[2]Number includes a mortality (No. S01).
[3]Number includes an immigrant (No. 166) and a mortality (No. 114).
[4]Number includes an immigrant (No. 165).

Bleach of both types gave variable, but for most purposes acceptable results. Care and consistency in mixing and applying bleach and monitoring the bleaching action were necessary. Accurately sketching final appearance helped make bleach marks effective in reidentifying monk seals. Angle of lighting, seal orientation, and current pelage condition (e.g. worn, sandy, wet) frequently made it difficult to perceive and read marks. However, inspection of a seal from various angles by an experienced observer was usually sufficient to discern and read a mark in reasonable time.

A seal was not considered to be in the marked population unless its mark was definitely resighted by at least two observers and judged of adequate conspicuousness, because of the variable, uncertain marking results. This requirement obviated two potential sources of inflated, cumulative population counts or inflated mark resight estimates. First, seals actually part of a "discrete" Lisianski population given a mark that did not persist would have increased the number of marks thought to be in the population, especially when later unknowingly given a different mark. Second, "transient" seals marked while only temporarily using Lisianski would also have inflated the number of marked seals calculated to be "sampled" during a census. Faintly bleached seals were considered marked only after they had been rebleached with a more conspicuous mark.

With respect to implications of transience or interisland movement, 11 of 26 numbers applied but never entered into the marked population as unique seals were later determined to be on seals bearing different conspicuous numbers. That is, the 11 were marked twice, but with different numbers. (Date of marking remained as assigned from this conspicuous number.) Six of the remaining 15 applied numbers that were unaccounted for were on seals known to have become wet within 10 min of application, and on another seal the bleach was immediately smeared by the seal's rolling.

None of the eight remaining seals (seven males and one female) had conspicuous scars that would have been recognized on resighting. In contrast, there was no failure to resight a seal that had good diagnostic scars when marked. As discussed earlier, there is other circumstantial evidence to indicate these and other bleach marks were not placed on transient seals, i.e., seals returning to some other atoll subpopulation.

Postmolt Re-Marking

Each of 215 seals marked at Lisianski was first so identified before its molt. All but two of these were correctly rebleached either in the summer by following seals through molt or on our return in October with the aid of sketches and photographs. The exceptions were two small juvenile males, including one (J13) that was not identified and most likely was never seen during October to November. The frequency with which this seal was seen during the week before our departure in mid-September suggested he was probably about to begin the premolt "fast," or the period spent on or close to shore, a phase displayed by nearly all other molters. The other male (J39) was bleach marked but not resighted after the mark was confirmed on 18 May. Although it was not conspicuously scarred, J39 matched the small size and sex of a molted juvenile male frequently seen in October and bleached with a new number, J45 (i.e., J39 and J45 may be the same animal).

All seals sighted in the autumn were either marked or, by 3 November, reidentified as known or probably known and then rebleached. Implications of these marking results at the population level are discussed later.

Tag Resights

Twelve pups tagged in 1982 still had both tags when last seen, which was September for one pup (023) and November for all others. One pup (025) lost a single tag early in the season, and was retagged.

Two adult females bore single Monel metal tags placed on them at Lisianski earlier. Seal A1011 (bleach marked A77) was tagged as a pup in 1971. Seal A86 (bleach marked 131) was tagged as a yearling in 1968. No other Lisianski seals were observed with metal tags.

A subadult male that grew to a large subadult or small adult this season was identified from a large conspicuous net scar on his neck. The constricting net was cut off in the spring of 1980 when the male was classed as a juvenile (Gilmartin[3]). It was photographed again on Lisianski during an island survey the spring of 1981 (Shallenberger[4]).

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[3] W. G. Gilmartin, Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, NOAA, P. O. Box 3830, Honolulu, HI 96812 pers. commun., July 1982.

[4] R. J. Shallenberger, U.S. Fish and Wildlife Service, Department of the Interior, P. O. Box 50167, Honolulu, HI 96850, pers. commun., December 1982.

Census

The frequency of alternate day censuses from March to September and in November seemed an adequate sampling of seal haul-out activity to represent individual patterns (Table 2). Although the number of seals on shore reached a maximum by about noon, experience showed that not all seals "using" the island on a specific census day were ashore, or at least counted, in that census period. Some seals sighted the previous night or seen in early morning had entered the sea by mid to late morning. Three adult females were known to have done this on several census days. Other individuals not counted on census sometimes hauled up in late afternoon. These included a few molting animals. Occasionally some individuals swimming nearshore were identified but not seen hauled out during that census or day, or seals known to be molting were not seen ashore that day. Therefore, a single census should not be considered as a total count of all seals or known individuals hauling out that day. Some individual seal, sex, or age biases in census data may exist due to this, though they are not understood. However, any such biases are assumed to be negligible over the long census series and contribute little to more identifiable sex and age related differences in haul-out frequency or duration. Conversely, documentation of multiple resights on censuses showed that almost all were adult males apparently engaged in searching beaches for mating purposes.

As the proportion of the seal population marked steadily increased, observer expertise in detecting and reading marks also increased. Bleach marks on new pelage usually gave better contrast than those on premolt pelage. Thus, later censuses are most complete and detailed.

On the average only 82 (38%) of the 215 known seals were present during any single spring and summer census. Census counts, excluding weaned and nursing pups, ranged from 58 to 108 ($\bar{x}$ = 82.0) for the 85 censuses 17 March to 12 September; including pups it ranged from 75 to 120 ($\bar{x}$ = 97.5). The 13 counts for October-November averaged lower, ranging from 60 to 81 ($\bar{x}$ = 68.8) excluding pups, and 69 to 95 ($\bar{x}$ = 81.8) including pups. The autumn counts were lower because the seals are generally not present on Lisianski for reproductive activities or molting that time of year.

Age Classification

The preferred sequence of age estimation of a seal in census before identification and recognition of that seal's assigned age class was not always possible to maintain. But over a census and especially over the census series, independence of these two events was complete enough to provide a good record of any observer biases or errors.

Four biases or errors in age classification were considered possible. Interobserver differences could result from an observer consistently classing specific seals older or younger than another observer might. Any such bias would have been constant. Midseason changes of one observer could have led to similar biases. Intraobserver inconsistency, or fluctuations in classifying the age of a specific size of seal either among observations on a census or among censuses, would have caused errors rather than a

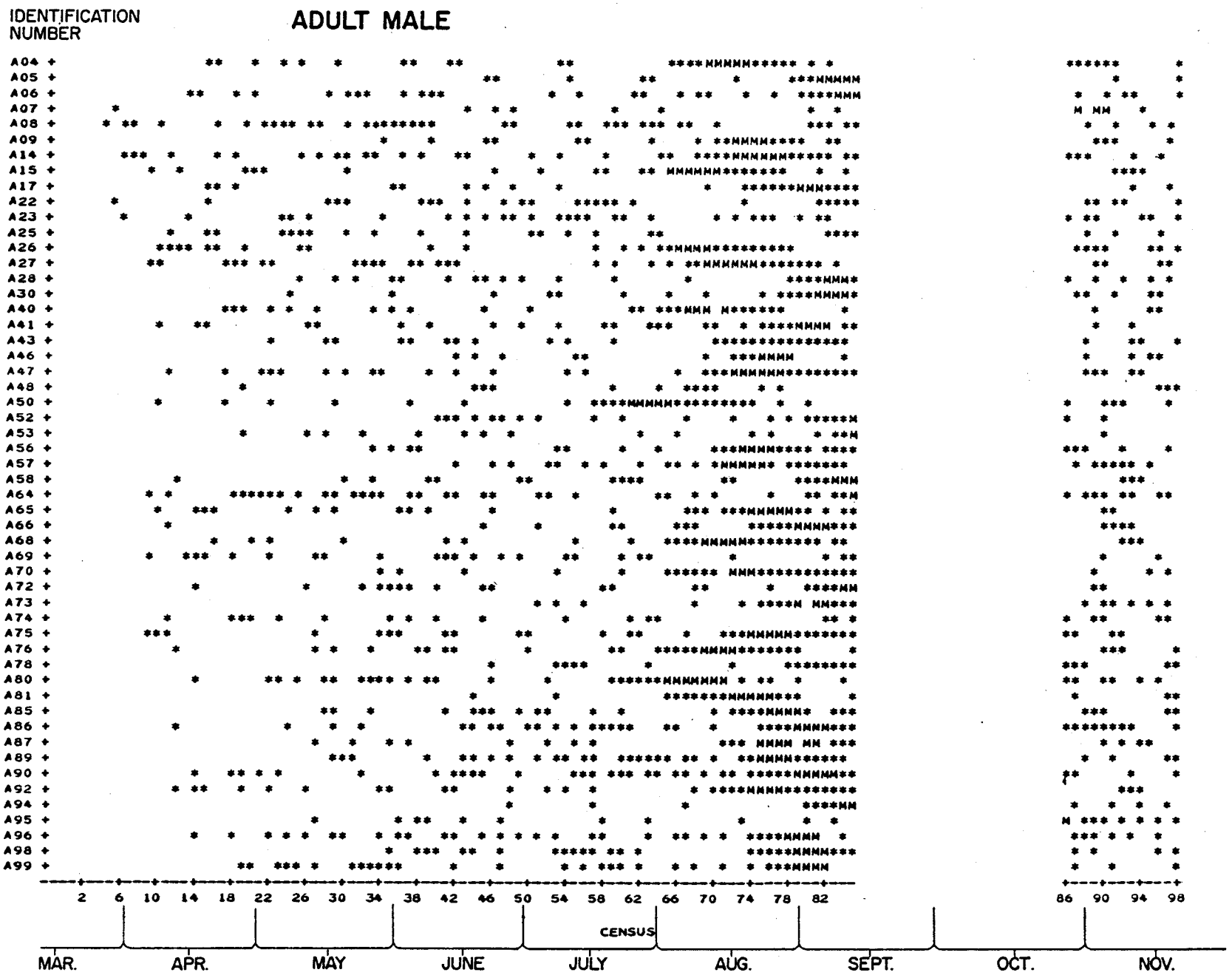
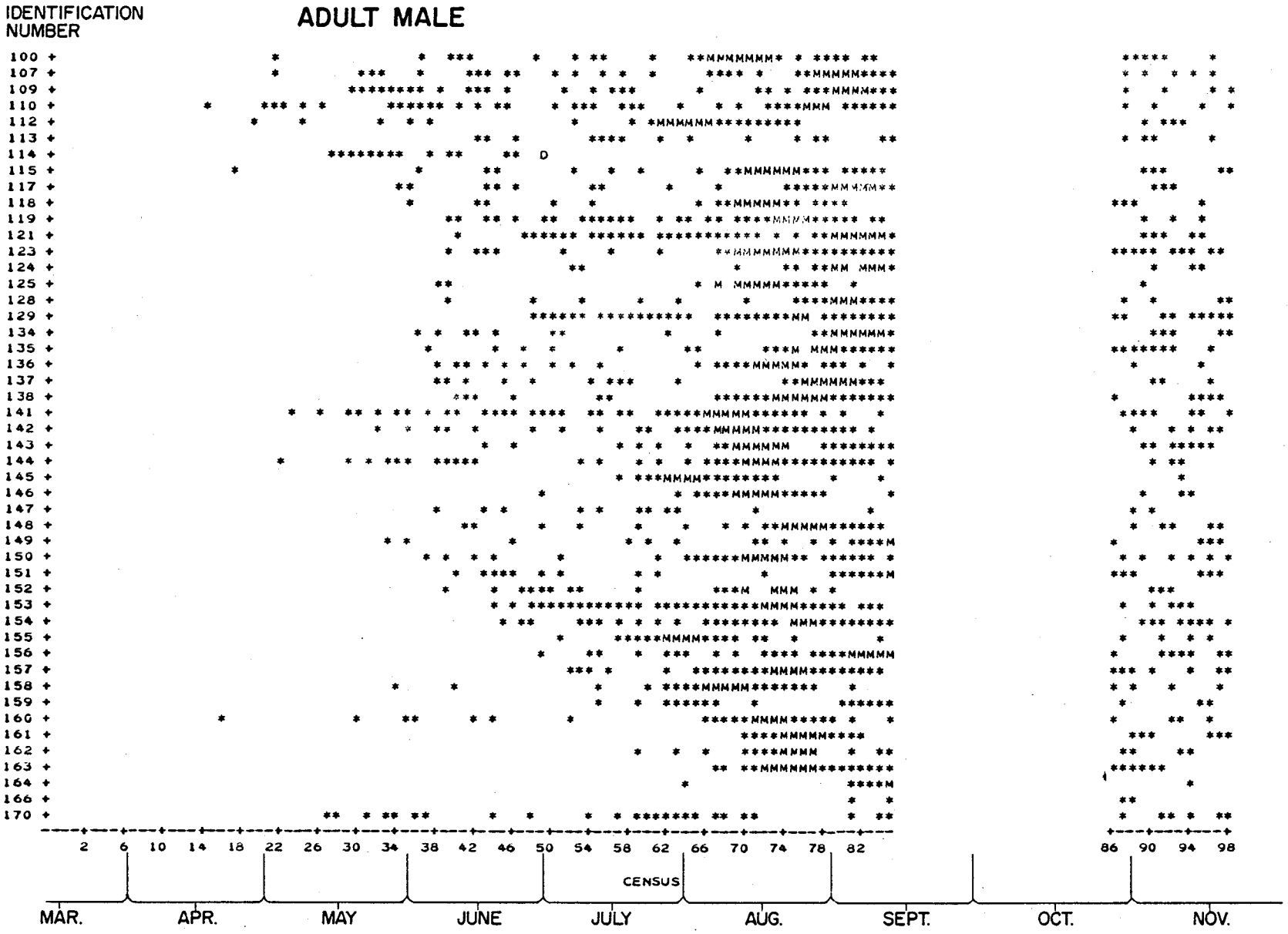


Table 2.--Individual monk seal hauling patterns by census number, Lisianski Island, 1982. (M: molting, B: first census pup observed with mother, P: mother-pup observed, and D: died).



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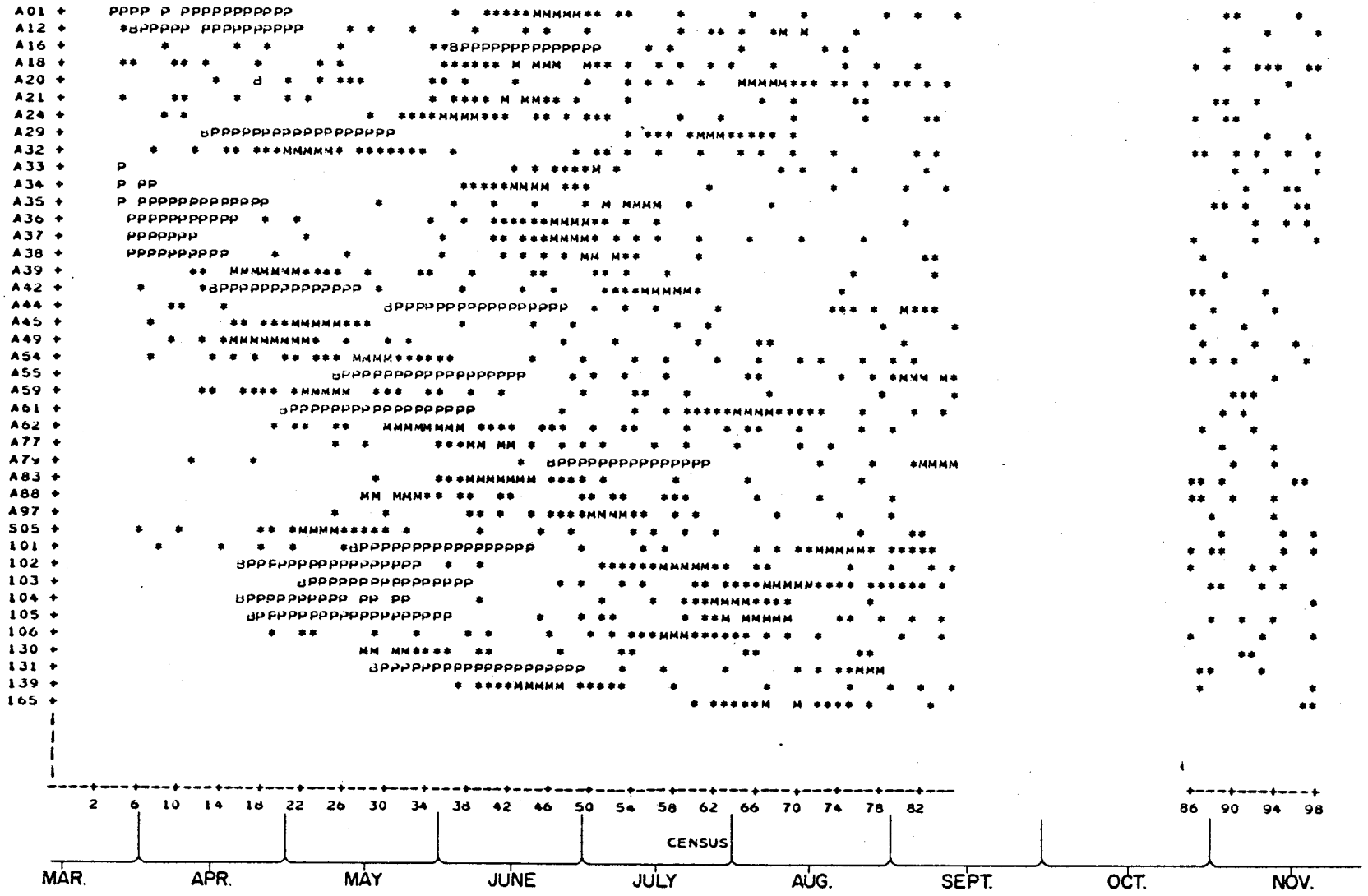

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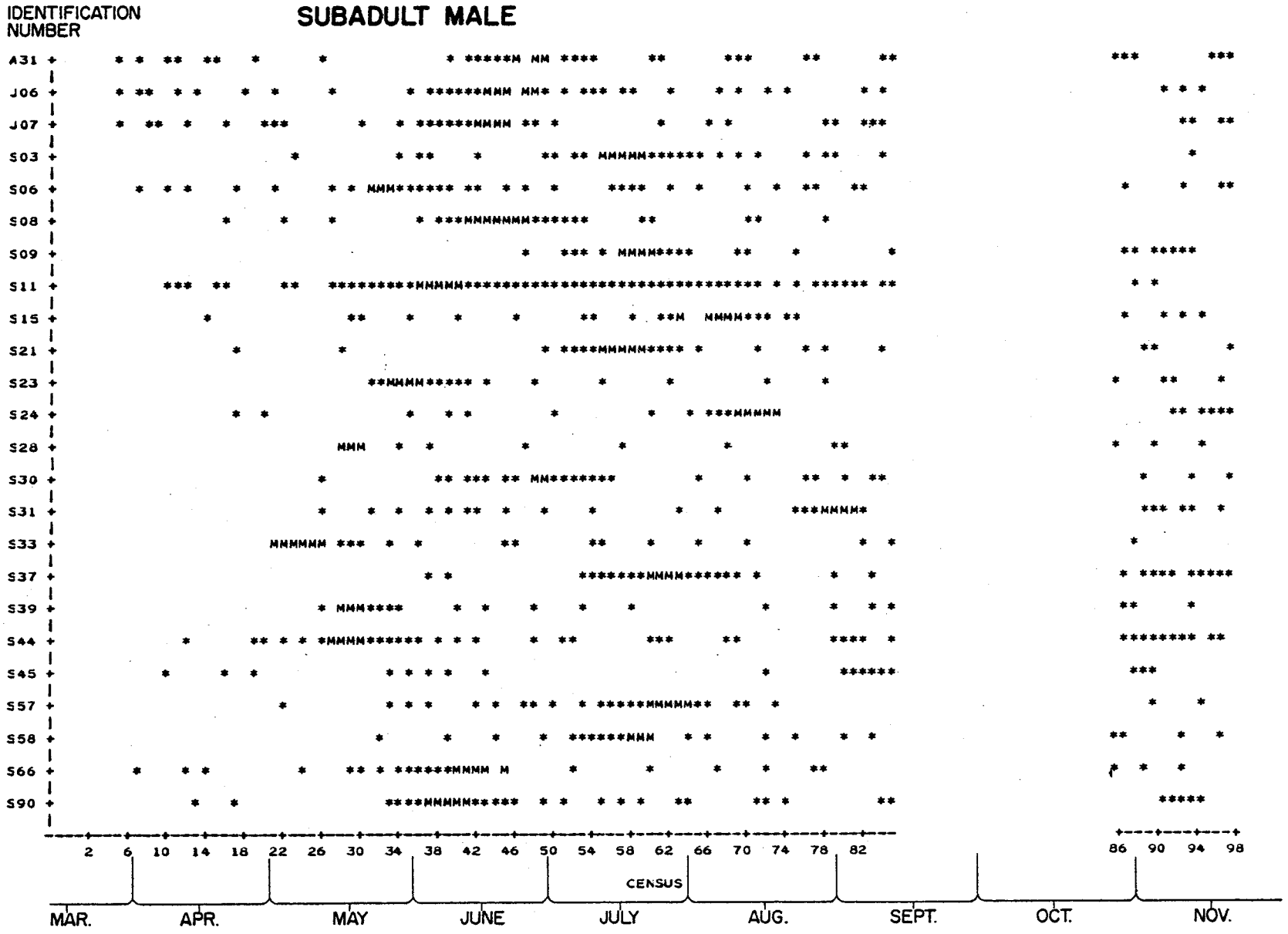

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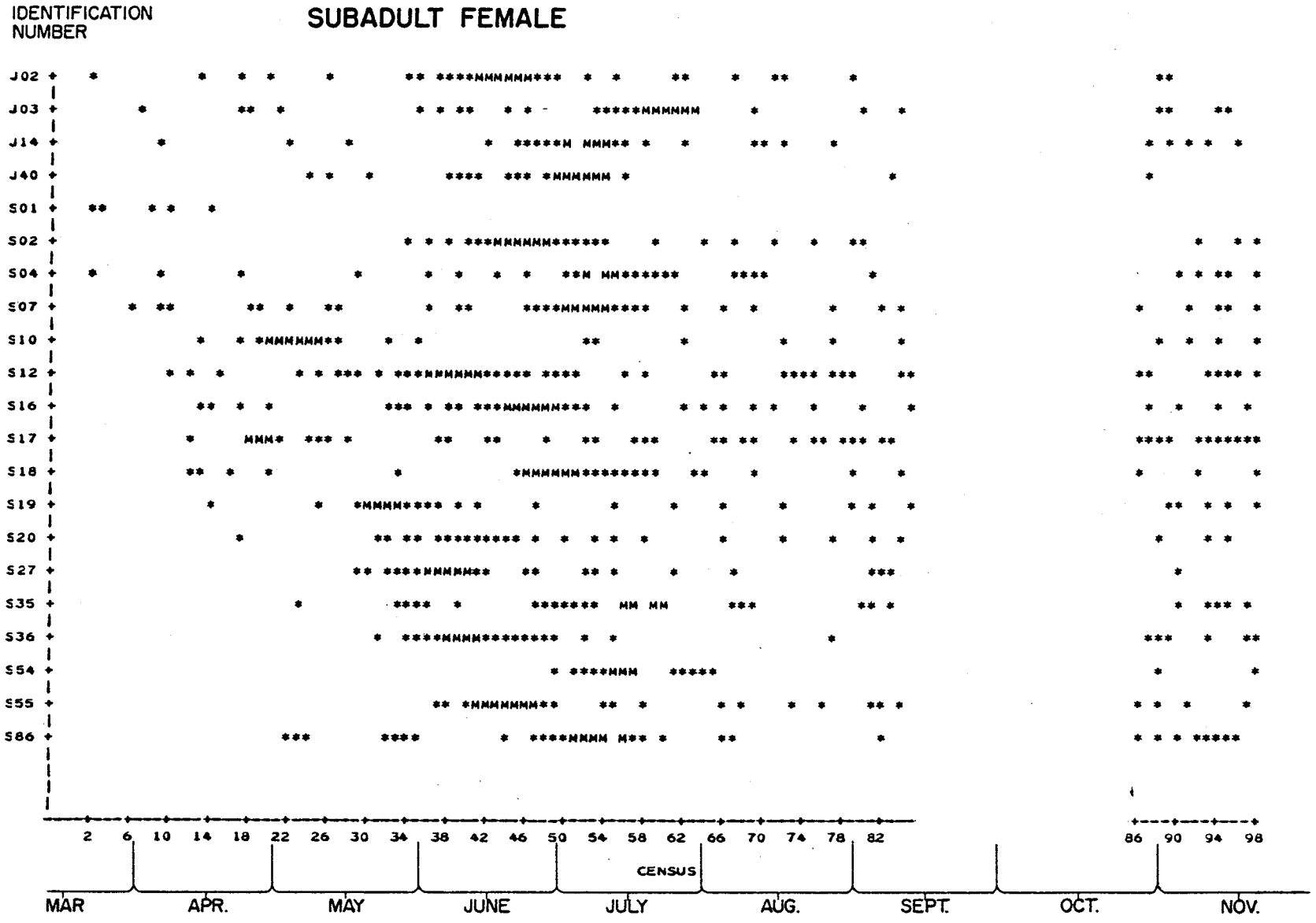

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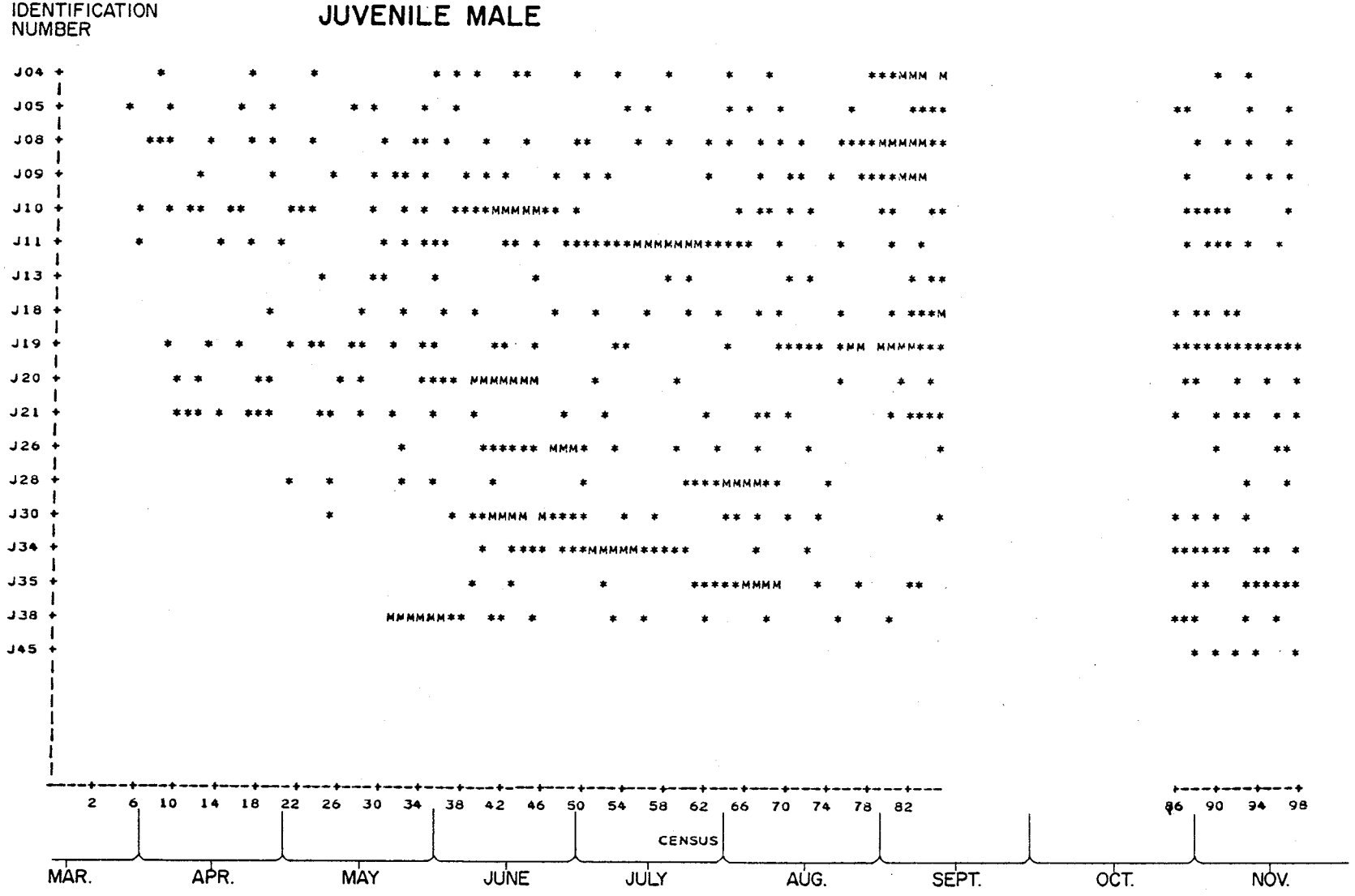

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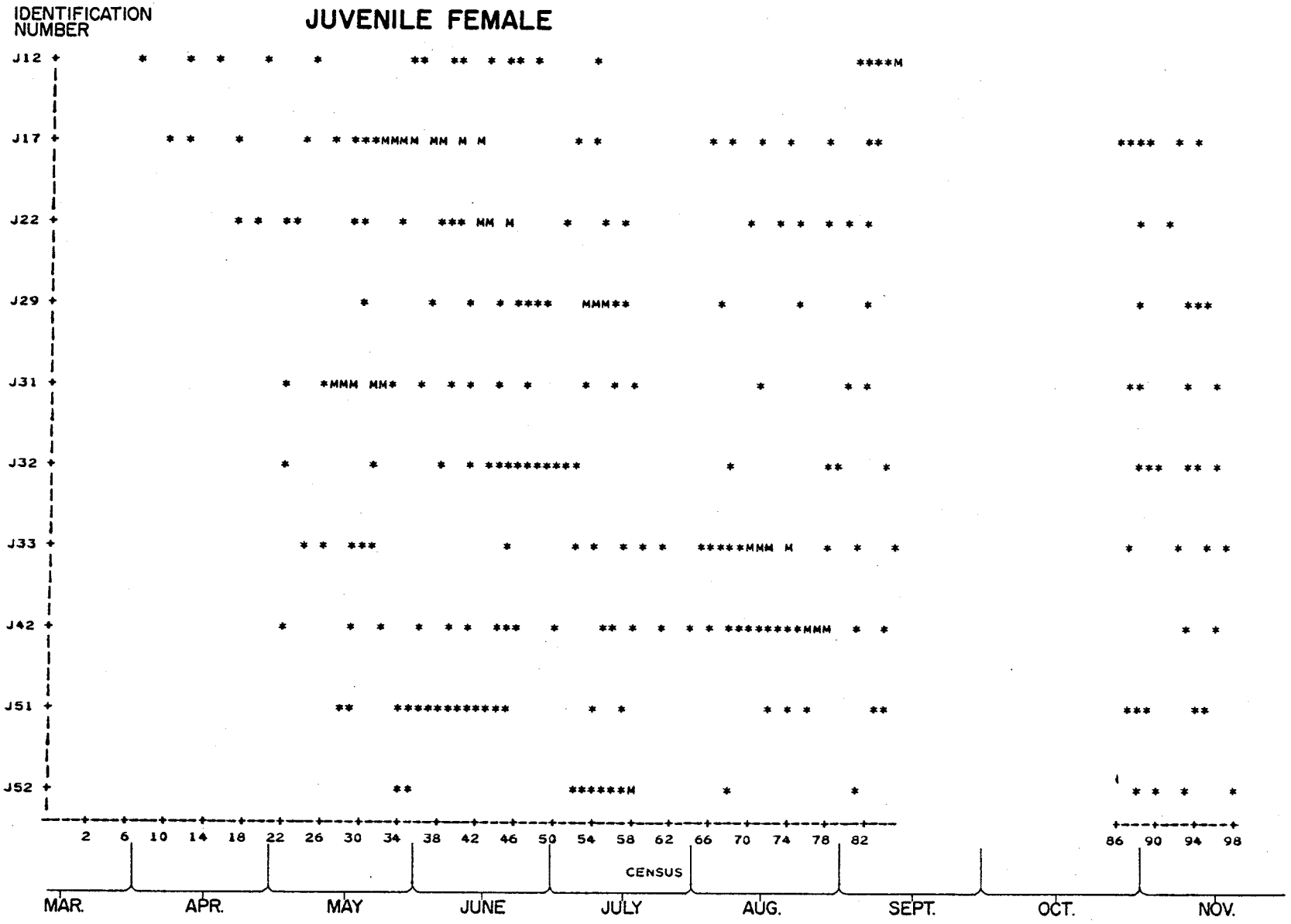

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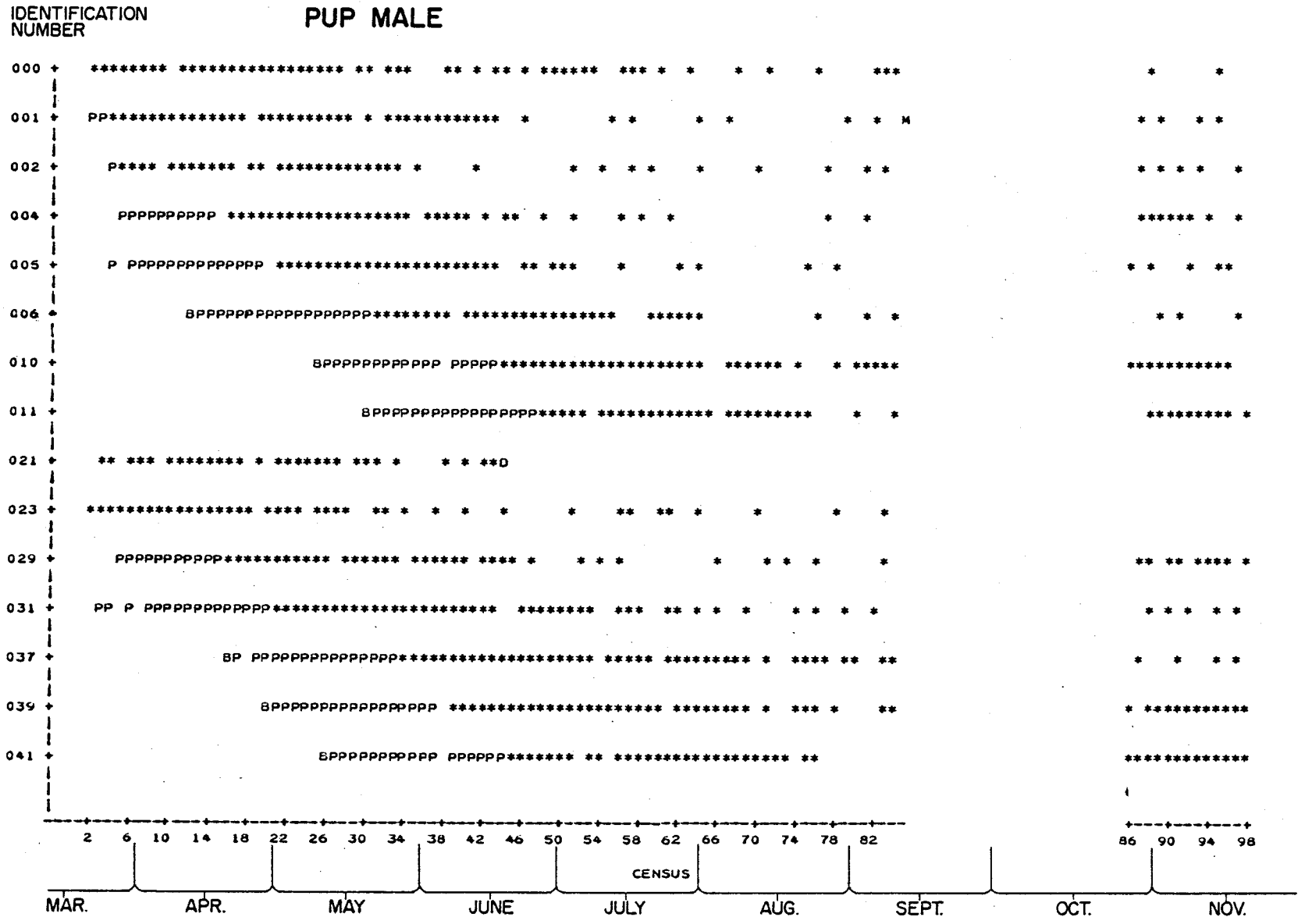

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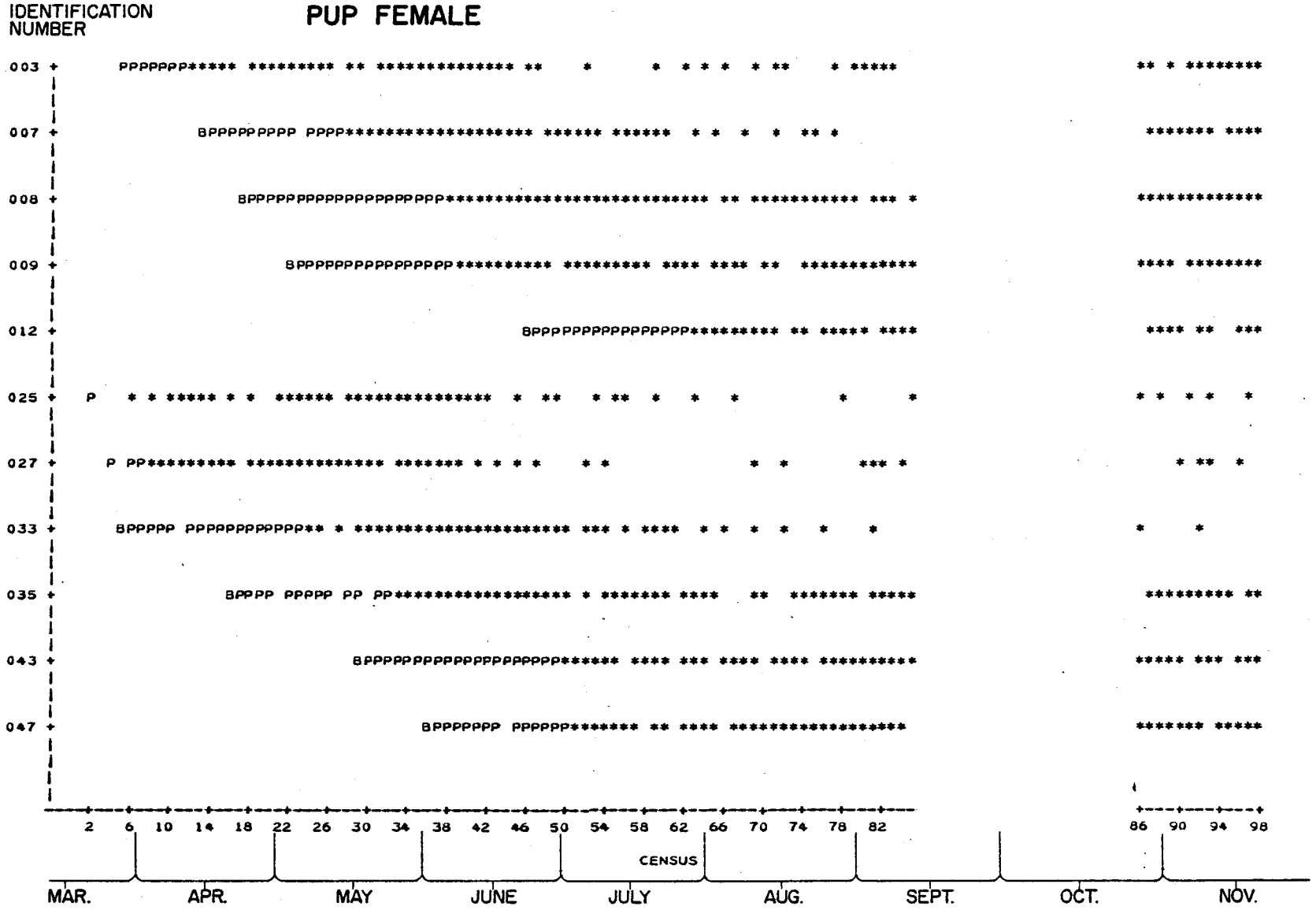

Table 2.--Continued.

constant bias. Intraobserver drift, an upward or downward trend in reference sizes for an age class, would also have led to errors, though in a single direction.

These factors could be important in three ways. First, in interpreting any discernible seasonal change in age distribution of seals counted, any artifacts of observer variation must be discounted. Sources of potential variation included initial intraobserver adjustment and standardization efforts in early spring and a mostly unmarked population early on that gave little feedback toward aging consistency. Inconsistent aging initially would have implied fluctuations in age composition that were not real and "floating" sizes of each age class being sampled. This latter process would make questionable any comparison between early season censuses and later ones, when age class size was more fixed, as well as any mark resight estimates dependent on having "closed," or fixed, sex and age classes.

Secondly, an increase in the independent age estimate of a known seal at some period in the season, from consistently in one class to consistently in the next greater, is an index of growth in that seal. If that is determined not to be part of a trend due to observer drift, then it may indicate a real change in age group structure. If growth from one age class to another over the season was found to be common enough, it must be considered in analyzing seasonal changes in age distribution among censuses.

Finally, awareness of interobserver differences is useful in direct comparisons of census and age composition data from other observers at other islands and years.

The concerted initial effort to develop and standardize age classification among all observers was continued until there was general understanding of criteria used and close agreement in aging. Concentration on this process quickly yielded consistent classification of age early in the census series. Spot comparison of independent age estimates among observers helped maintain this standardization. On site intraobserver comparisons of independent estimates on known seals with previously assigned ages also helped reinforce the procedure and reduce any tendency toward observer drift.

No persistent biases in census taking were identified. The most common sources of any error seemed to be uncontrollable factors that would be encountered by and influence all observers, such as a seal being wet or lying in an unusual orientation, age estimates having to be made at a greater distance than usual, and adjusting aging criteria and estimates for postmolt seals to account for weight loss and pelage change. Therefore, I conclude, provisionally, that analyses of census data and comparisons among seals, groups, and seasons were not seriously influenced by observer variation.

Results of Mark and Census Effort: Population Level

The 215 seals marked at Lisianski constitute a discrete, almost closed population or subpopulation, within the Northwestern Hawaiian Islands. An absolute count was accumulated through individually marking all seals before molt and documented by continuing census procedures and effort to collect haul-out data and maintain a totally marked population. Table 2 shows sightings by census of individually marked seals including pups, grouped by sex and age class as classed at midsummer. Events observed on censuses such as marking, birth, weaning, death or disappearance, and molt are indicated. Table 3 lists totals by census for each sex and age category recorded. Two definitions of this population are discussed, one indirect and circumstantial, the other concise but less widely applicable, for two different purposes.

Population Defined by Haul-Out Observations

That all seals and only those seals that haul out with some minimum frequency on Lisianski define the population, and that all such seals were marked, and therefore the entire population was marked, is circular reasoning. The implicit assumption is that all seals in the population (such as those utilizing resources on Neva Shoal or contributing to reproduction) do haul out on land with some regularity.

Fortunately, this tautology in practice seems applicable, and the assumptions valid. There is no evidence that any seals using local waters do not haul out, and virtually all available haul-out sites at Lisianski were readily visible. All marked seals were known to haul out before or after molt at times unassociated with this process, which appears to be the only obligatory haul-out time other than pupping. Even the last seals to be marked in midsummer were frequently resighted thereafter. So their sequence of marking is not necessarily correlated with a low haul-out probability, and no link between bleach marking and increased haul-out frequency is known. Therefore, all seals resident in the waters around an atoll can be expected to haul out frequently enough to be marked, i.e., at least twice. What must be determined from census results is the best time and necessary length of field stay to accumulate and document population data with acceptable confidence and precision.

Population Defined By Molting Seals

A biologically concise definition of the Lisianski population in 1982 is those seals that molted there, plus seals known to have died before molting. All seals molt annually, spending much or all of that time ashore. All molting or recently molted seals were marked, and thus the entire population was marked. This definition can be justified for this year, but is probably not applicable to other years.

All known resident seals (except for one that cannot be documented) molted between mid-April and early November, within the overall dates of our extended field season. Presumably, any seal actually resident in that population would have molted within this period. Individual molt periods

Table 3.--Summary of Lisianski Island monk seal censuses, 1982 (M = male, F = female, ? = sex unknown).

Census	Date 1982	Adult			Subadult			Juvenile			Total no pups	Pups						Total including pups
												Weaned			Nursing			
		M	F	?	M	F	?	M	F	?		M	F	?	M	F	?	
1	3/19	22	14	18	3	1	7	6	3	4	78	--	--	--	1	1	7	87
2	3/23	30	14	12	2	6	4	3	5	4	80	2	--	--	2	1	5	90
3	3/25	24	12	4	4	1	8	--	3	2	58	3	--	--	2	--	6	69
4	3/27	31	17	11	7	5	5	4	2	1	83	4	--	--	3	2	3	95
5	3/29	24	14	24	6	3	6	2	2	1	82	4	--	--	2	2	2	92
6	3/31	33	18	7	5	2	3	6	5	3	82	5	1	--	4	3	--	95
7	4/2	25	14	11	9	4	5	2	3	5	78	5	--	--	3	3	--	89
8	4/4	35	18	11	2	6	8	5	3	4	92	5	2	--	4	2	--	105
9	4/6	36	11	9	4	7	6	6	4	3	86	3	1	--	4	2	--	96
10	4/8	32	15	6	7	4	7	5	3	4	83	4	2	--	4	2	--	95
11	4/10	31	14	14	5	2	7	3	3	1	80	5	2	--	4	1	--	92
12	4/10	33	20	4	11	4	2	6	3	1	84	5	3	--	5	1	--	98
13	4/14	22	16	10	7	7	4	4	1	2	73	5	3	--	5	2	--	88
14	4/17	32	17	8	9	4	4	2	2	2	80	5	3	--	5	2	--	95
15	4/19	38	19	7	4	2	4	3	3	1	81	5	2	--	4	2	--	94
16	4/21	29	14	11	7	2	6	5	2	1	76	7	3	--	4	3	--	93
17	4/23	24	20	7	6	6	11	5	3	1	83	6	--	--	4	4	--	97
18	4/25	29	19	8	1	4	4	6	2	--	73	5	3	--	3	4	--	88
19	4/27	29	18	8	7	5	1	9	3	2	82	6	2	--	4	4	--	96
20	4/29	26	18	6	5	9	4	3	2	1	74	5	2	--	4	4	--	89
21	5/1	33	20	9	7	3	1	5	--	1	79	9	3	--	3	3	--	97
22	5/3	35	18	7	8	5	2	3	6	--	84	9	3	--	3	5	--	104
23	5/5	31	19	6	13	4	2	6	2	--	83	9	3	--	3	4	--	102
24	5/7	22	14	20	4	8	2	3	3	1	77	8	4	--	3	4	--	96
25	5/9	28	21	15	4	6	2	7	2	--	85	9	4	--	4	4	--	106
26	5/11	24	20	15	9	5	2	2	2	1	80	9	3	--	5	4	--	99
27	5/14	26	15	14	6	4	--	2	2	1	70	8	2	--	5	3	--	88
28	5/16	31	21	9	11	3	5	5	2	--	87	7	4	--	5	3	--	106
29	5/18	33	21	5	10	6	--	5	7	--	87	7	5	--	5	4	--	108
30	5/20	34	17	5	8	3	--	4	4	--	75	8	4	--	6	3	--	96
31	5/22	26	17	1	7	4	--	4	5	--	64	8	5	1	5	4	--	87
32	5/24	31	18	4	8	7	--	7	4	--	79	9	4	--	5	4	--	101
33	5/26	41	17	5	10	10	--	2	2	--	87	9	6	--	5	3	--	110
34	5/28	36	20	3	13	11	--	9	5	--	97	8	6	--	4	3	--	118
35	5/30	43	24	--	12	10	--	9	4	--	102	8	6	--	4	3	--	123

Table 3.--Continued.

Census	Date 1982	Adult			Subadult			Juvenile			Total no pups	Pups						Total including pups
												Weaned			Nursing			
		M	F	?	M	F	?	M	F	?		M	F	?	M	F	?	
36	6/1	41	21	--	12	9	--	6	4	--	93	7	6	--	4	4	--	114
37	6/4	32	21	--	13	9	--	7	3	--	85	8	6	--	4	4	--	107
38	6/6	31	20	1	10	10	--	4	4	--	80	9	7	--	1	3	--	100
39	6/8	36	19	--	15	12	--	7	5	--	94	8	8	--	3	2	--	115
40	6/10	29	17	--	10	10	--	7	4	--	77	10	7	--	3	2	--	99
41	6/12	27	19	--	12	10	--	7	5	--	80	8	8	--	3	2	--	101
42	6/14	40	18	--	14	10	--	8	4	--	94	9	7	--	3	2	--	115
43	6/16	35	16	--	11	9	--	8	4	--	83	9	7	--	3	2	--	104
44	6/18	27	20	--	8	10	--	7	5	--	77	9	6	--	2	1	--	95
45	6/20	29	18	--	11	10	--	8	6	--	82	7	7	--	1	2	--	99
46	6/22	34	16	--	7	13	--	3	4	--	77	9	6	--	1	3	--	96
47	6/24	22	20	--	8	13	--	5	3	--	71	8	6	--	1	3	--	89
48	6/26	26	15	--	10	13	--	5	3	--	72	9	6	--	--	3	--	90
49	6/28	23	24	--	10	13	--	7	2	--	79	9	5	--	--	3	--	96
50	7/2	27	19	--	9	11	--	8	2	--	76	9	6	--	--	2	--	93
51	7/4	25	15	--	9	10	--	4	2	--	65	12	5	--	--	1	--	83
52	7/6	23	14	--	10	14	--	6	5	--	72	8	9	--	--	1	--	90
53	7/8	32	23	--	13	13	1	6	3	--	91	7	7	--	--	1	--	106
54	7/10	32	14	--	10	10	--	5	6	--	77	7	7	--	--	1	--	92
55	7/12	32	12	--	12	13	--	3	4	--	76	6	7	--	--	1	--	90
56	7/14	25	14	--	8	10	--	5	4	--	66	11	7	--	--	1	--	85
57	7/16	33	14	--	11	8	--	3	5	--	74	10	6	--	--	1	--	91
58	7/18	24	13	--	11	10	--	5	3	--	66	8	6	--	--	1	--	81
59	7/20	41	14	--	10	6	--	4	1	--	76	7	8	--	--	1	--	92
60	7/22	33	15	1	13	4	--	5	--	--	71	7	7	--	--	1	--	86
61	7/24	29	12	--	10	6	--	4	2	--	63	8	3	--	--	1	--	75
62	7/26	32	12	--	11	7	--	7	--	--	69	8	6	--	--	1	--	84
63	7/28	39	11	--	9	3	--	6	--	--	68	6	8	--	--	--	--	82
64	7/30	39	11	--	8	4	1	8	1	--	72	11	7	--	--	--	--	90
65	8/1	38	14	--	9	3	--	5	1	--	70	4	5	--	--	--	--	79
66	8/3	39	17	--	7	8	--	4	3	--	78	5	6	--	--	--	--	89
67	8/5	54	15	--	8	6	--	10	2	--	95	6	6	--	--	--	--	107
68	8/7	51	9	--	8	4	--	6	5	--	83	7	5	--	--	--	--	95
69	8/9	52	10	--	10	8	--	7	2	--	89	6	8	--	--	--	--	103
70	8/11	56	13	--	10	2	--	6	3	--	90	5	5	--	--	--	--	100

Table 3.--Continued.

Census	Date 1982	Adult			Subadult			Juvenile			Total no pups	Pups						Total including pups
												Weaned			Nursing			
		M	F	?	M	F	?	M	F	?		M	F	?	M	F	?	
71	8/13	58	4	--	8	3	--	3	4	--	80	7	7	--	--	--	--	94
72	8/15	62	10	--	9	6	--	5	3	--	95	3	7	--	--	--	--	105
73	8/17	61	8	--	4	3	--	3	2	--	81	3	5	--	--	--	--	90
74	8/19	62	12	--	3	1	--	2	4	--	84	5	7	--	--	--	--	96
75	8/21	70	12	--	5	4	--	6	3	--	100	5	6	--	--	--	--	111
76	8/23	65	12	--	6	2	--	3	2	--	90	7	7	--	--	--	--	104
77	8/25	66	10	--	6	6	--	4	1	--	93	3	8	--	--	--	--	104
78	8/27	68	6	--	8	2	--	3	5	--	92	4	7	--	--	--	--	103
79	8/31	66	10	--	8	6	--	5	1	--	96	3	7	--	--	--	--	106
80	9/2	69	9	--	7	5	--	9	2	--	101	3	6	--	--	--	--	110
81	9/4	69	12	--	5	6	--	5	4	--	92	4	8	--	--	--	--	104
82	9/6	65	11	--	8	5	--	9	5	--	103	4	8	--	--	--	--	115
83	9/8	66	9	--	6	4	--	9	3	--	97	7	7	--	--	--	--	111
84	9/10	72	8	--	9	7	--	8	4	--	108	6	6	--	--	--	--	120
85	9/12	63	7	--	8	4	--	10	2	--	94	1	6	--	--	--	--	101
86	10/27	27	12	--	5	6	--	7	3	--	60	4	5	--	--	--	--	69
87	10/29	39	9	--	8	6	--	9	5	--	76	6	7	--	--	--	--	89
88	10/31	36	9	--	7	9	--	10	8	--	79	9	7	--	--	--	--	95
89	11/2	38	13	--	7	6	--	7	3	--	74	7	8	--	--	--	--	89
90	11/4	46	8	--	9	7	--	9	2	--	81	7	6	--	--	--	--	94
91	11/6	38	7	--	8	4	--	6	1	--	65	9	6	--	--	--	--	80
92	11/8	36	10	--	6	5	--	5	2	--	67	8	6	--	--	--	--	81
93	11/10	29	8	--	11	8	--	11	5	--	73	7	8	--	--	--	--	88
94	11/12	31	9	--	9	9	--	4	4	--	68	5	5	--	--	--	--	78
95	11/14	25	7	--	7	9	--	5	3	--	61	8	3	--	--	--	--	72
96	11/16	35	5	--	4	5	--	6	3	--	60	5	7	--	--	--	--	72
97	11/18	32	7	--	9	5	--	8	1	--	63	6	9	--	--	--	--	78
98	11/19	31	11	--	7	10	--	6	1	--	67	4	7	--	--	--	--	78

were usually well defined, and ranged from as little as 5 or 6 days, to 12 days, and occasionally longer. All marked seals molting during our actual presence were seen molting on several or more days. For any seal molting during our presence to have gone unmarked was extremely unlikely.

Fourteen marked seals were not seen molting, either before 14 September or after 25 October. All of these molted presumably on Lisianski during our absence. Twelve were definitely reidentified after they molted, and one equivocally (J45 may equal J39). The last (J13) may have been close to molting when we left in September. All unbleached seals seen on our return in October-November could be accounted for from these 14.

Each seal marked in 1982 was generally marked at least a week before its molt. Thus molting apparently did not cause seals that rarely hauled out otherwise to come ashore. Postmolt seals of all groups were commonly seen; there were few or no immediate and prolonged returns to sea. That an unknown seal would have hauled out, undergone a week or more of premolt "fast" characteristic of most seals, molted for 8 days or more, returned to sea, all between 13 September and 26 October, and not be identified by 22 November, seems unlikely. Thus all evidence indicates that all resident seals molted at Lisianski and that all were marked.

Applicability of Combined Population Criteria

The molt criterion discussed above cannot be consistently applied for defining island subpopulations in future years. Molting seals have been sighted in every month (Gilmartin footnote 3) and seasonal distribution of molt in the different sex and age groups can vary from island to island. Field seasons will most likely not last as long as this year's extended coverage on Lisianski, much less for complete years. But since molt distribution of the population fell within our field dates this year, this criterion is verification that a totally marked population based on time-specific haul-out patterns can be accumulated. In future seasons, seals that are seen to molt can be used as a sample of their sex and age group. If marking a seal can be documented as temporally independent of molt, and if all those seals starting molt are known seals, these representative samples can be a good indicator that most or all of their particular sex and age groups have been marked.

Finally, the one or two apparent exceptions to these criteria for defining and counting a population actually clarify the definitions while showing their limitations. These exceptions are the two documented incidents of immigration, more fully discussed under interisland movement later. Adult female 165, the last female marked, almost certainly was seen and marked on her first appearance at Lisianski on 22 July. Her haul-out probability before was virtually zero because she was known to be lactating on Laysan much of that time. She was recognized only because a biologist on Laysan had sketched and photographed her extensive scars. Otherwise, her long prior absence would have severely weakened an assumption of similar haul-out probability and likelihood of marking. Thus, although seal 165 molted on Lisianski (and appeared to undergo estrus there), and by this criterion was considered part of the Lisianski population, we know merely

by chance that she contributed reproductively to the Laysan population in 1982. And, therefore, potential limitations in defining populations due to interisland movement are demonstrated, as is the potential importance of this phenomenon generally.

Adult male No. 166, the last male marked, possessed several distinctive scars and natural light pelage spots and was very likely identified the first time it hauled out on 4 September at Lisianski. This situation also could necessitate consideration of greater haul-out probabilities in identifying all seals in a subpopulation or in documenting an estimate. That seal 166 is not in the resident population may seem a semantic argument and a way to fit seals into formal definitions, but the biological aspects are important. He was emaciated and possessed barnacles and dense algal growth in his pelage, indicating he had been at sea a long time, apparently without feeding much on Neva Shoal, or elsewhere. He was the only unmolted seal on Lisianski by 22 November, and this delay, as well as perhaps his inclination to remain near Lisianski from early September through November, may have depended directly on his nutrition or health. He first appeared after all breeding for the year seemed long over, and his functional residence in the Lisianski population can best be determined in future seasons from resight data.

Population Structure

Table 1 shows the monk seal population at Lisianski in 1982 (less pups) by sex and age. The ratio of males to females increases greatly from immaturity to adulthood even if juveniles and subadults are pooled to increase sample size and minimize aging discrepancies. Neither the causes nor the effects of this skewed ratio in favor of males are fully understood.

Reproduction

At least 28 pups were born in 1982: 16 males, 11 females, and 1 of undetermined sex. The sex of the latter could not be determined because it was found as a deteriorated carcass with remnants of black natal pelage in March. One male pup died at or near birth. The mother (A20) had sustained a large, deep back wound, of the type known to be inflicted by adult males, about 1 or 2 weeks before parturition. Twenty-two of the mothers were known, but two females that weaned pups a few days after our arrival were never successfully reidentified from scars sketched before they left. One of the two tagged females (No. 131, tag No. A86) pupped this year and in 1980; the other (No. A77, tag No. A1011) did not pup in this 1982 season. Assuming the 40 classified adult females (excluding No. 165) constituted the actual adult female group this pupping season, at least 70% pupped, and 65% (26) weaned. This pupping rate is high compared with about 38% for 1964 and 1965 from 78 tagged adult females on Kure Atoll (Wirtz 1968). There, only 44 (56%) pupped in that 2-year period. On Laysan Island, 56 identifiable adult females were seen in 1977, when 55% pupped, and 1978, when 50% pupped (Johnson and Johnson 1981b); 79% pupped in that 2-year period. Part of the variation may be due to difference in age classification of females. But size differences between females classed as adult and subadult on Lisianski seemed consistently clear-cut. If anything, the

inclusion as adult of two females (A18 and S05) that seemed slightly smaller than most parturient females would underestimate the pupping rate if these two were not sexually mature or were just maturing but nonparous. Identification of parturient females in 1983 on Lisianski should give a more complete estimate of definitely mature females from which to calculate productivity rates.

Mortality Factors

Death or Disappearance

Besides the two perinatal deaths, three other deaths and a possible disappearance were documented. Male pup 021 was killed 19 June, most likely by one or more adult males, since a male was attending the carcass in the surf of a small cove where males were observed pursuing pups at other times. No gross external nor any gross internal injuries were present.

Male pup 023, one of the three oldest pups, was last seen 8 September when about 7 months old. From 26 October through 22 November, in addition to censuses, daily tallies were made of all marked seals seen, thus undoubtedly he was absent this entire period. Several other small juveniles were absent longer than this at various times. Some such juveniles could well have been less than a year old, since births have been recorded in every month (Gilmartin footnote 3) and 5- to 6-month-old pups were increasingly classified as juveniles on census. On Laysan, 4- to 7-month-old pups were occasionally not sighted for 3 to 4 weeks, albeit on a less frequent census schedule (Johnson and Johnson 1981b).

Most of the skin and much of the blubber from the back of subadult female S01 were missing when she was first seen 21 March. She was periodically seen ashore until 17 April, and the wound looked much the same. She disappeared and probably died because of her severe wound and emaciated condition. The cause is most likely attributable to biting by adult males.

The two lactating females (originally A02 and A13) whose scars were sketched but who were not reidentified after weaning are assumed to have been marked with another number rather than to have disappeared. However, it is at least plausible that postweaning estrus instigated wounding by adult males (Johnson and Johnson 1981b). This could have contributed, along with postlactating emaciation, to death or to greater susceptibility to shark predation. Three adult females received large, open back wounds after being marked this season, and twice, several males were seen nearshore vigorously pursuing or biting another adult--at least one, a female. A fourth female had a healing but still open wound when first identified in March, and two more still had small healing spots in the middle of large dorsal scars. Two of these four females that had open wounds actually received them before pupping this year.

Adult male 114 died on 13 July after being physically restrained for attachment of a dive recorder. Necropsy showed no obvious cause of death, but microscopic histopathology revealed several chronic ailments

debilitating the seal. Two of the 10 foreflipper nails were not excessively worn or broken, but longitudinal sectioning (Hofman 1975) of these revealed no countable laminae.

Injury

Evidence of shark attack was also seen. A healthy appearing adult male (A95) when marked, sustained severe shark bites on the right fore and hind flippers and pelvic region in early summer. He lost enough weight that ribs and vertebrae were clearly visible at later resights, then slowly began regaining weight and healing by midsummer. In late October, he had sloughed some injured hind flipper tissue and exposed phalangeal bone and was still healing. Seal A95 was one of the last three adult males molting then. At least three other adult males bore scars suggesting prior wounds at least this severe. But no immature seals had large, obvious shark inflicted scars, implying these smaller seals do not readily escape and recover from shark attack (Wirtz 1968).

Entanglement in Nets and Debris

A final documented cause of potential death this season was fishing gear entanglement. Four weaned pups this year (Henderson 1984) were cut from tightly encircling masses of net. The subadult male (S21) with the recognizable neck scar had been found as a juvenile with tightly encircling line and a deep, septic neck wound. No adults had identifiable net scars, nor any subadults but the one above. Apparently younger seals tend to entangle themselves and usually do not survive (Fiscus et al. 1978; Andre and Ittner 1980).

A juvenile female (J22) had a transverse scar across the bridge of the nose possibly due to entanglement. Another pup had a plastic band tightly stuck on her snout that we pulled off, and at least four other small seals had a plastic ring, bucket, or shredded bag loosely and temporarily around their necks. So, fishing gear is not the only debris that is a problem source. This curiosity and attraction to lost or discarded nets, lines, and other debris, on land and in water were commonly observed, most often among immature seals (cf. Fiscus et al. 1978). These anecdotal observations suggest that entanglement can be a frequent and fatal problem that may be selective for young seals.

Interisland Movement

Only two movements to Lisianski were documented this season, and no emigration was documented. A large, extensively scarred female first appeared 22 July and was identified by sketches and photographs taken at Laysan Island. This seal (No. 165) had weaned a pup on Laysan in late June this year. Once at Lisianski, she continued to haul out periodically and went through apparent estrus when she was attended by an adult male. She molted there and was rebleached, and was then resighted several times through November.

On 4 September, an emaciated adult male (No. 166) with distinctive natural pelage marks and scars appeared ashore. His pelage was quite green with algae, and seven live gooseneck barnacles, Lepas spp., ranging in estimated capitulum length from a few millimeters to a centimeter, were attached to his dorsal pelvic hair, indicating a long period at sea. Johnson and Johnson (1978) described three such observations of barnacles. They noted an adult male on Laysan in 1977 that returned from a 4-month absence with gooseneck barnacles on his pelage. The barnacles were gone from the Laysan seal after 2 days ashore, and from No. 166 after a similar period. An adult female, not seen on Laysan from 6 June to 9 August 1977, reappeared with all parts of the body covered with barnacles, which disappeared 6 days after resighting. And in mid-August an adult thought to be a male was seen at Maro Reef with barnacles on the head and neck (Coleman[5]). Seal No. 166 had not been seen before on Lisianski in 1982, but thereafter including November was commonly seen. He regained weight but did not molt, and molt did not appear imminent by 12 November. Recognition of these two seals (No. 165 and No. 166) in a future season will further clarify subpopulation discreteness and age specific tendencies to move.

Lack of evidence for more extensive interisland movement during this 1982 field season was apparent. Researchers on Laysan from March through June did not see any marked seals from Lisianski. From 29 April to 11 May, 2-6 July, and 27-31 October no marked seals from Lisianski were seen at Pearl and Hermes Reef. Conversely, although at least 37 different seals were marked on Pearl and Hermes Reef during these visits, and some probably re-marked after molting, no marked seals from there were seen at Lisianski. Some bleach marks were not seen in their entirety and therefore could not be read, but it is extremely unlikely that any of these were on seals from Pearl and Hermes Reef and were not seen again later and fully identified.

Seal censuses were also being regularly carried out at French Frigate Shoals, and some bleaching was done and censuses taken at Kure Atoll simultaneously with most of our field season. Again, no interisland movement was documented through these activities.

The subpopulations may then be discrete by short-term measures even though seals from Lisianski were frequently at sea long enough to move to and from other atolls or banks. Understanding the role of interisland movement would be valuable in short-term population marking and estimation, and in long-term investigation of dispersal and population trends or shifts of the entire species.

SUMMARY

The Hawaiian monk seal population utilizing Lisianski Island was counted and studied by marking seals and taking complete island censuses

[5]R. Coleman, U.S. Fish and Wildlife Service, Honolulu, notation from cruise log, Maro Reef, 6 August 1977.

from 17 March to 14 September and 26 October to 22 November 1982. Methods used and preliminary results obtained included:

1. Individually marking sleeping seals using commercial bleach, plus some reliance on natural scars and marks, is a feasible technique for identifying all sex and age classes. This method provides little risk of disturbing the seals. During lactation females and pups were not bleached, to avoid any such risk.

2. Two hundred fifteen monk seals other than recent pups were marked, sexed and subjectively classified by age as juvenile (18 males and 10 females), subadult (24 males and 21 females), and adult (101 males and 41 females). The adults included one parous female that moved from Laysan Island and one male that very likely moved from another unknown island. Thus for 1 year a "resident" and perhaps almost discrete population in terms of population dynamics was defined.

3. At least 28 pups were produced by 40 adult females, and 26 weaned. This 70% reproductive rate is very high compared with reported rates of monk seals at other islands.

4. Natural deaths included two pups that died near birth, a weaned pup apparently killed by an adult male, and a subadult female with a severe back wound probably inflicted by adult males. Similar back wounds were observed on several adult females including a high proportion of extensive, healed, dorsal scars. One adult male died after human restraint and was found to have been chronically ill.

5. Besides deaths due to adult male aggression, perhaps related to the very skewed sex ratio, entanglement in fishing net and debris was observed to be a potential cause of death particularly among young seals, including a significant proportion of weaned pups. Data on shark wounding indicated that they also may cause deaths particularly among young seals.

6. The series of every second day censuses provided extensive, detailed records on individually known seals. Analyses of these data should provide insight into sex-, age-, and season-specific haul-out patterns and sighting probabilities, as well as any influence on these patterns, of such biological events as reproduction, molting, and injury. This quantitative information may be useful as a basis for understanding population discreteness and interisland migration, planning and conducting future population assessments at other islands, and monitoring trends in population size, structure, and productivity.

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